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**AERATED LAGOONS FOR POTATO PROCESSING
WASTES**

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AERATED LAGOONS FOR POTATO PROCESSING WASTES

Kenneth A. Dostal**

INTRODUCTION

Production of potatoes in the United States has increased from 19.5 billion pounds per year in 1951 to about 29.5 billion pounds per year in 1968.⁽¹⁾ The four western states of Idaho, Washington, California, and Oregon accounted for most of this increase. In fact, from 1958 through 1968 the production by these four states increased 5.1 billion pounds; almost twice the increase of 2.6 billion pounds for the whole United States.

A considerable amount of this increased production can be attributed to the increased processing of specialty items such as french fries, hash browns, etc. The quantity of frozen potato products has increased from 129 million pounds in 1955 to about 1.5 billion pounds in 1966. A ten-year projection made by DuPont⁽²⁾ predicted an increase of 170 percent to nearly 4 billion pounds in frozen products from 1966 to 1976 with an expected population increase of about 9 percent for the same period.

Processing of a ton of potatoes results in wastes with a population equivalent of about 500. Thus, the current

waste load generated by processing plants is equivalent to about 10 million people. Even if all processors had primary treatment, which they do not, the discharged effluents would be equivalent to nearly 5 million people. Nearly one-fourth of this quantity is discharged in the State of Idaho, thus it is apparent why the Potato Processors of Idaho Association has been working on various studies on secondary treatment of potato processing wastes.

In 1964 the consulting firm of Cornell, Howland, Hayes & Merryfield was retained by the Potato Processors of Idaho Association to assist in the design and operation of secondary treatment, pilot plant facilities. As a result of this work⁽³⁾, design criteria were established for secondary treatment by activated sludge, trickling filter and conventional stabilization ponds. One of the conclusions of this work was: "Additional study should be given to determine more closely the capabilities of these systems in secondary treatment of potato processing wastes". This, coupled with the fact that both trickling filter and activated sludge treatment plants have high capital and operating

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costs, prompted the initiation of the study reported herein.

In July 1966 a request to the regional office of FWQA was received from the Idaho State Health Department for technical assistance in the development of secondary treatment methods for potato processing wastes. A memorandum of understanding was signed by the three participants: Potato Processors of Idaho, Idaho State Health Department, and FWQA.

The objectives of this study were to investigate two possible methods of secondary treatment:

- (1) A surface-aerated aerobic lagoon, and
- (2) An anaerobic lagoon followed in series by a surface-aerated aerobic lagoon.

DESCRIPTION OF FACILITIES

The pilot plant facilities were located at the site of a processor's primary waste treatment plant in Burley, Idaho. This treatment plant receives the wastes from three potato processing plants which process over 1,000 tons of potatoes per day. Two of the plants account for 87 percent of this weight and produce french fries, flakes, granules, and other potato specialties. The remaining 13 percent of the potato tonnage is processed in a starch plant.

A flow diagram of the processor's full-scale primary waste treatment plant is shown on Figure 1. Waste streams from the three processing plants are combined in a receiving tank prior to passage through two 5-foot diameter, 10-foot long rotary drum screens. Solids retained on the 20-mesh screens are removed and stored in bins. The screened waste then enters a 100-foot diameter primary clarifier which operates at an overflow rate of about 800 gallons per day per square foot. Effluent passes through a Parshall flume prior to discharge to the Snake River. Sludge from the primary clarifier is thickened in a centrifuge and also stored in bins. Both the screenings and the thickened sludge are trucked to cattle feedlots and used for feed.

Figure 2 shows a flow diagram of the pilot plant facilities used for this study. Three earthen ponds lined with gunite were used. Each pond was 40-feet square at the water surface and approximately 10-feet deep which resulted in a volume of about 50,000 gallons each. Primary clarifier effluent was pumped to aerobic pond I and anaerobic pond II. Overflow from pond II was pumped to aerobic pond III.

Pond I contained a 10-horsepower fixed aerator. The second pond was covered with three-inch thick styrofoam blocks to help retard heat loss and control odors. A pump was installed to recirculate the contents from the bottom to the top so that the anaerobic pond would be completely mixed. Pond III contained a 5 horsepower floating aerator. Sample locations were as follow:

1. Primary clarifier influent after screening,
2. Primary clarifier effluent,
3. Pond I effluent,
4. Pond II effluent, and
5. Pond III effluent.

OPERATION

The pilot plants were operated for two processing seasons of 9 to 10 months each. During the first season, pond I was not in operation because of late arrival of the 10 horsepower aerator. The hydraulic loadings were varied

over a wide range so that a spectrum in results would be obtained. Feed rates in most of the runs were in the 3 to 15 gallons per minute range which resulted in theoretical detention times of 2 to 10 days. When all three ponds were in operation, the feed rate to ponds II and III, which were in series, was twice the feed rate to pond I. This resulted in equal over-all detention times through the two systems.

As mentioned earlier, the facilities were sampled routinely in five locations. Hourly grab samples were taken for eight hours and composited. In general, analyses were performed according to Standard Methods⁽⁴⁾ and included pH, alkalinity, temperature, dissolved oxygen, settleable solids, BOD, COD, organic carbon, ammonia, nitrite, nitrate, Kjeldahl nitrogen, total and orthophosphate, as well as total, suspended, total volatile, and volatile suspended solids. During the second season, soluble COD, BOD, and organic carbon were also run.

RESULTS

Table 1 shows the average quantities of waste constituents generated per ton of potatoes processed. These figures are averages for the two-year study and are based upon the concentrations measured in the primary clarifier influent — after passage through the two 20-mesh screens. As shown, 4,200 gallons of fresh water were used per ton of raw potatoes and the waste stream contained 90 pounds of BOD, 210 pounds of COD, 110 pounds of SS, 0.6 pounds of total phosphate as P, and 3.5 pounds of total nitrogen as N.

Table 2 presents some of the results on the primary clarifier influent and effluent. Since both main processing plants used caustic peeling, the waste had a high pH. The influent had a median of 11.3 and effluent 10.4. Temperature drop across the clarifier averaged 4°F from 78 to 74. It is readily apparent that the BOD, COD, and SS concentrations varied considerably. Influent BOD averaged 2,730 mg/l with a standard deviation of ±790 mg/l. The effluent averaged 1,600 mg/l for a reduction of 41 percent. The COD was reduced by 45 percent, and the SS by 73 percent. In addition, total nitrogen and total phosphates were reduced by 21 percent.

The effluent from the clarifier which was the feed to the lagoons had an average BOD:N:P ratio of 100:5.2:0.9 although this ratio varied markedly from one day to the next. This is almost the same as the often quoted requirement of 100:5:1 for aerobic biological treatment.

A summary of the data collected on aerobic pond I is shown in Table 3. The three runs with average detention times of 7.8, 4.2, and 10.4 days had average BOD loadings of 11, 24, and 10 lbs/day/1000 cu.ft., respectively. Reduction in total BOD, that is with the suspended solids in the effluent, ranged from 55 to 82 percent. Reduction of COD across the pond ranged from 31 to 61 percent. Effluent suspended solids ranged from 630 to 700 mg/l, thus, they contributed considerable BOD and COD. This is shown by the column under BOD₅ which is based on centrifuged effluent samples. Reduction in soluble BOD ranged from 76 to 95 percent.

Table 4 presents some of the data collected on anaerobic pond II. Since most of the runs were made at relatively high hydraulic rates and the contents were completely-mixed, percentage organic reductions were very low. The primary purpose of this pond was not BOD

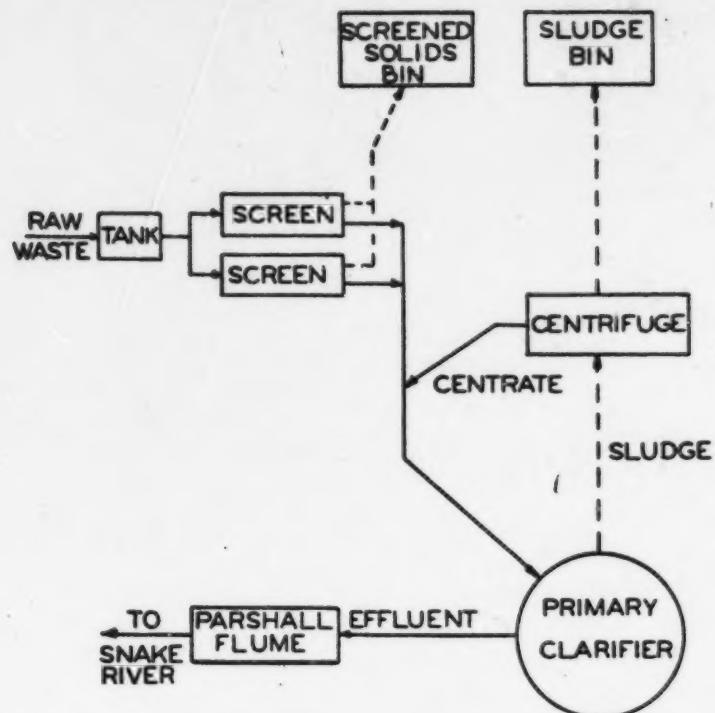


Figure 1. Flow diagram of primary treatment plant

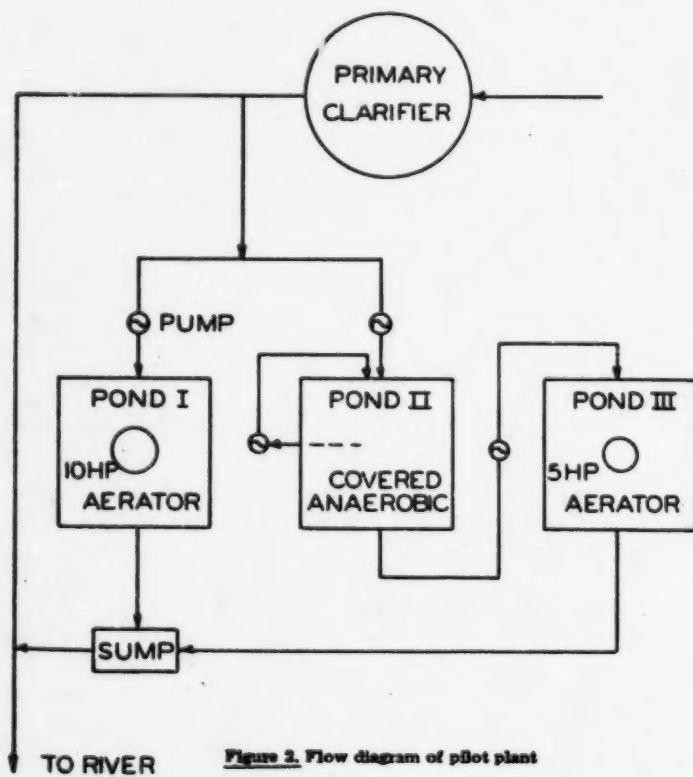


Figure 2. Flow diagram of pilot plant

Table 1 - Waste Production Per Ton of Potatoes Processed

Parameter	Quantity*
Quantity, gal.	4200
BOD, lbs	90
COD, lbs	210
SS, lbs	110
T-PO ₄ as P, lbs	0.6
T-Nit. as N, lbs	3.5

*Measured after screening

Table 2 - Operational Characteristics of Primary Clarifier

		Clarifier Influent	Clarifier Effluent	Removal %
pH	Range Median	10.6-12.1 11.3	7.1-11.6 10.4	--
Temp. °F	Range Median Std. Deviation	68-82 78 ±3	63-79 74 ±3	--
BOD mg/l	Range Mean Std. Deviation	1220-5150 2730 ±790	650-2570 1600 ±390	41
COD mg/l	Range Mean Std. Deviation	3120-9860 5390 ±1520	1440-6000 2960 ±750	45
SS mg/l	Range Mean Std. Deviation	280-5900 2320 ±1150	80-3190 620 ±490	73
TKN as N mg/l	Range Mean Std. Deviation	73-225 107 ±28	38-175 84 ±25	21
TPO ₄ as P mg/l	Range Mean Std. Deviation	7.2-45.1 18.0 ±6.9	6.0-37.2 14.2 ±6.1	21

Table 3 - Data Summary for Aerobic Pond I

Run No.	D.T. days	Temp. °F	COD*		SS*		VSS*		BOD*		BOD _s *	
			In	Out	In	Out	In	Out	In	Out	In	Out
1	7.8	44	2210	860	490	630	440	560	1410	270	1060	70
2	4.2	44	2160	1480	470	700	420	610	1580	710	1440	340
3	10.4	47	2390	1190	310	650	280	620	1700	310	1440	75

Run No.	LOADINGS - lbs BOD/day			Reduction - %		
	Acre	1000 cu.ft.	lb. MLVSS	COD	BOD	BOD _s
1	1840	11	0.32	61	81	93
2	3870	24	0.62	31	55	76
3	1660	10	0.26	50	82	95

*mg/l

Table 4 — Data Summary for Anaerobic Pond II

D.T. days	Temp. °F	lbs BOD/day/ 1000 cu.ft.	BOD		BOD Red. %	COD		COD Red. %
			In	Out		In	Out	
30	54	3.3	1550	780	50	3110	1640	47
8.8	61	11	1460	1180	19	3950	2510	36
5.1	68	22	1770	1600	10	3280	2930	11
2.4	71	46	1690	1520	10	3400	2880	15
7.8	62	12	1470	1240	16	2190	1570	28
2.1	63	45	1500	1460	3	2210	1770	20
3.1	62	34	1690	1610	5	2280	2170	5
5.2	68	19	1610	1410	12	2390	2000	16

Table 5 — Data Summary for Aerobic Pond III

Run No.	D.T. days	Temp. °F	COD		SS		VSS		BOD		BODs	
			In	Out	In	Out	In	Out	In	Out	In	Out
1	8.8	39	2380	1400	250	730	240	630	1150	180		
2	5.1	44	2930	1250	490	820	420	790	1600	270		
3	2.4	56	2910	2160	260	860	210	710	1510	640		
4	3.9	44	1540	860	410	580	360	510	1150	380	980	80
5	2.1	43	1770	1600	400	810	360	650	1460	730	1350	485
6	3.1	43	2170	1300	470	890	410	790	1670	550	1470	190
7	5.2	50	2150	1100	410	510	340	500	1480	370	1440	110

Run No.	LOADINGS - lbs BOD/day			Reduction - %		
	Acre	1000 cu.ft.	lbs. MLVSS	COD	BOD	BODs
1	1500	8	0.21	41	84	
2	3660	20	0.40	57	83	
3	7400	40	0.88	26	58	
4	3000	18	0.58	44	67	92
5	7150	44	0.96	10	50	64
6	5460	33	0.68	40	67	87
7	2900	18	0.57	49	75	92

Table 6 - Values for Constants

Constant	Values*	
	Pond I	Pond III
a	0.63	0.63
b	0.06	0.06
k	0.64	1.1
K _s	110.	140.
c	$\frac{1.7 - \log(t)}{2.5}$	$\frac{1.7 - \log(t)}{2.5}$

*for temp ~ 45°F

reduction, but to see if the molecular structure of the waste constituents could be altered so that they would be degraded faster aerobically in pond III. As shown, most of the runs were made at detention times less than 9 days with BOD loadings in the 11 to 46 lbs/day/1000 ft³ range. For these runs, the BOD reduction averaged less than 20 percent.

A summary of the data collected from pond III is shown in Table 5. The hydraulic detention time ranged from 8.8 days to 2.1 days. As the load was increased from 8 to 44 lbs BOD/1000 cu.ft./day, the BOD reduction decreased from 84 to 50 percent. Soluble BOD reduction for the last four runs ranged from 64 to 92 percent at BOD loadings of 18 to 44 lbs/1000 cu.ft./day.

DISCUSSION

In order to make the data collected on the three ponds useful to others, it was desirable to use existing equations and develop the necessary constants to that the kinetics could be adequately described.

The following three equations⁽⁵⁾ were used to calculate the effluent soluble BOD, MLVSS and total BOD, respectively, from the two aerated cells:

$$s = \frac{K_s(1+bt)}{akt - (1+bt)} \quad (1)$$

$$M = \frac{(F_0 - s)(K_s + s)}{kst} \quad (2)$$

$$BOD_T = s + cM \quad (3)$$

where:

F₀ = total influent BOD, mg/l

BOD_T = total effluent BOD, mg/l

s = soluble effluent BOD, mg/l

M = MLVSS or effluent VSS, mg/l

t = detention time, days

a = growth yield constant

b = microorganism decay constant, day⁻¹

k = maximum rate of BOD utilization per unit weight of microorganism occurring at high BOD concentration, day⁻¹

K_s = half velocity constant equal to the BOD concentration when the rate of BOD

utilization is equal to one-half the maximum rate, mg/l

c = BOD equivalent of the effluent VSS

The values derived from the pilot plant data for the various constants are tabulated in Table 6. As shown, the values for the growth yield constant, "a", and the microorganism decay constant, "b" were the same for both aerobic ponds. As others have observed, the value of "c" varied with sludge age or for this study, hydraulic detention time. The main difference between the two aerated cells was in the value of "k", the maximum rate of BOD utilization. The value of 1.1 for pond III was 70 percent greater than the value of 0.64 for pond I.

Although the percentage BOD reduction across anaerobic pond II was rather small, the pond apparently altered the molecular structure of the more complex organic materials such that they were degraded more rapidly aerobically in pond III. Additional benefits could also result from the use of an anaerobic pond preceding an aerobic pond in a full-scale installation. First of all, without mixing in the anaerobic pond, the effective MLVSS in the anaerobic pond would build up with time and the BOD reductions across the pond would increase accordingly. Secondly, anaerobic-aerobic ponds in series with the anaerobic pond covered would have less temperature drop than an aerobic pond with a detention time equal to that of the two ponds in series. This would increase the rate of BOD utilization in the combined anaerobic-aerobic ponds over than in the straight aerobic system.

The rate of BOD utilization in anaerobic pond II was best described by the following equation:

$$BOD_T = F_0 - 34 t (1.04)^{T-20} \quad (4)$$

where:

T = temperature, °C

Since only the total influent BOD was needed for aerobic pond III, no attempt was made at developing equations to predict the soluble BOD or VSS in the effluent from anaerobic pond II.

The final report⁽⁶⁾ on this study compares the measured BOD and SS effluent values with those calculated using the four equations and constants shown above. In general, very good agreement was obtained - in most cases - within the accuracy limits of the analytical tests.

CONCLUSIONS

Conclusions drawn from this two-year study are as follow:

1. Over 90 percent BOD reduction can be obtained by primary clarification, plus either an aerobic lagoon or anaerobic-aerobic lagoons in series.
2. Both systems are economically feasible, the choice will depend upon local costs and conditions.
3. The BOD reduction across the ponds can be adequately described by available models for which the necessary constants were derived from this study.
4. Chemical additions were not necessary for either pH control or inorganic nutrient adjustment.
5. A method of removal of suspended solids from the effluent will probably be required for most applications.

FULL-SCALE FACILITIES

Since this study was reported nearly a year ago, it is of interest to note what use, if any, has been made of the information generated. At least three full-scale systems have been designed and built as a result, at least in part, of the work reported above. Gray and Osborne, consulting engineers in Yakima, Washington, have recently completed two installations on potato processing wastes. Both locations have primary treatment followed by complete-mixed aerated lagoons. One is located in Quincy, Washington, and it had a design load of about 28,000 lbs BOD/day with a flow of 1.8 mgd. The aerated lagoon contains four 150 horsepower aerators and provides 9.6 days detention time. It is followed by stabilization ponds or settling cells which provide 26.4 days detention time.

The second system is located in Warden, Washington. The design load was 10,900 lbs BOD/day with a flow of 1.1 mgd; three 75 horsepower aerators were employed. A 10-day detention time was selected and it is followed by three settling cells which provide a detention time of about 15 days.

Both of these systems are in operation, but operating data are not currently available. It is of interest to note that they both employed a rather long detention time in the aerated lagoon. This was to ensure the conversion of most of the soluble BOD into suspended solids. The long settling times should assure good removal of the suspended solids and thus, good overall treatment.

The third system mentioned earlier has been designed and construction is nearly complete. This work is being

partially supported by an FWQA R&D grant to the City of Grand Forks, North Dakota. The waste to be treated consists of domestic plus effluents from three potato processing plants. Flow will range from 3.2 to 4.2 mgd and the BOD load will range from 11,000 to 25,000 lbs/day depending upon number of processing plants in operation. The existing system for the City consisted of four stabilization ponds with a total surface area of 640 acres. An 18-month study will investigate the use of four cells in various combinations to pretreat the waste before discharging into the stabilization ponds. Two of the cells are complete-mix aerated lagoons and two are complete-mix, covered anaerobic units. Each of the four cells is 15 feet deep and has a volume of 8.4 million gallons. The first 12 months of operation call for one-half the flow to go to an anaerobic cell followed in series by an aerated cell. The remaining flow will be split evenly between the other anaerobic and aerobic cells which will be operated in parallel. The last 6 months of the study will involve the use of all four cells in series, two anaerobic followed by the two aerobic units.

Data from full-scale installations will be forthcoming in the next 6 to 12 months at which time the derived constants can be substantiated or revised, if necessary.

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AERATED LAGOON TREATMENT OF LONG ISLAND DUCK WASTES

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Introduction

The production of ducks for slaughter is a large agri-business on Long Island, New York. Approximately seven million ducks are raised in Suffolk County, the easternmost county of Long Island, each year. This production represents about sixty-five per cent of the total restaurant and domestic duck supply of the nation. Other duck production areas are located in Virginia, California,

and midwestern states such as Wisconsin and Illinois. While the recorded presence of the duck industry on Long Island can be traced back to 1824, duck production reached its present level by World War II. Today the industry on Long Island is worth approximately 30 million dollars.

The number of ducks raised on Long Island has remained relatively constant for the past 25 years, however, the number of farms has decreased. In 1959, 49 farms were engaged in duck raising (1), while today approximately 35